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U.S. Federal Power Commission

Report...uses of the Stanislaus River

Washington

1927

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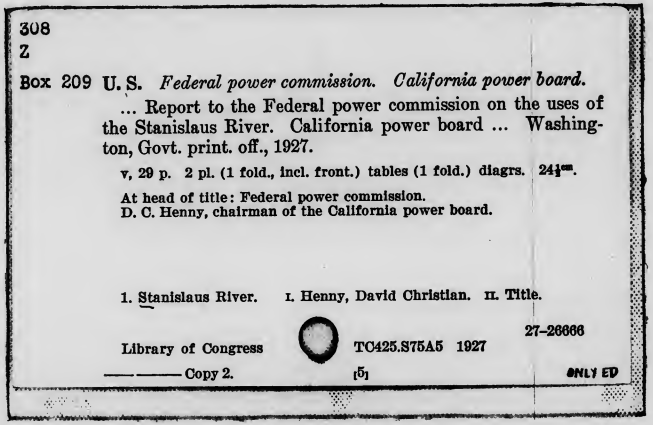

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REPORT TO THE
FEDERAL POWER COMMISSION

ON THE

USES OF THE STANISLAUS RIVER CALIFORNIA

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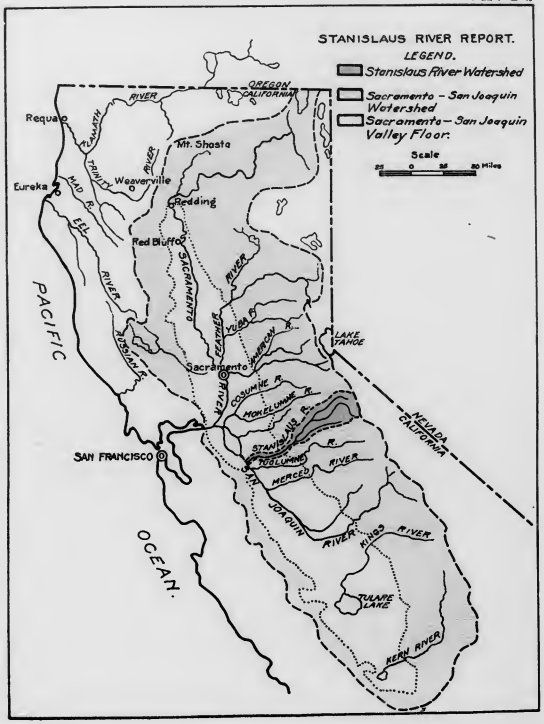
PLATE I.



FEDERAL POWER COMMISSION

REPORT

TO THE

FEDERAL POWER COMMISSION

ON THE

USES OF THE STANISLAUS RIVER

CALIFORNIA POWER BOARD

D. C. HENNY . Consulting Engineer, Bureau of Reclamation, *Chairman*
Department of the Interior

U. S. GRANT, 3d . . Major, Corps of Engineers, United States Army
War Department

E. W. KRAMER . . . . . Hydraulic Engineer, Forest Service
Department of Agriculture

W. F. McCLURE . . . State Engineer and Director of Public Works
State of California

UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON
1927

Cal JAN 17 1928

FEDERAL POWER COMMISSION

THE SECRETARY OF WAR, *Chairman*
THE SECRETARY OF THE INTERIOR. THE SECRETARY OF AGRICULTURE
O. C. MERRILL, *Executive Secretary*

LETTER OF TRANSMITTAL

SAN FRANCISCO, *December 1, 1924.*

Mr. O. C. MERRILL,
Executive Secretary, Federal Power Commission,
Washington, D. C.

SIR: The board of engineers appointed by you to make a general study of the North Fork of the Stanislaus River in California, with special reference to a pending application contemplating the creation of storage on a tributary of the said fork, submits its report herewith.

D. C. HENNY, *Chairman,*
U. S. GRANT, 3d,
E. W. KRAMER,
W. F. MCCLURE,[2]
Board of Engineers.

[1] Certain changes in the report as submitted by the board have been made in the office of the Federal Power Commission in order to include information obtained since the original report was written, and minor changes of an editorial nature have also been made. The changes are not of sufficient importance to affect the original findings, conclusions, or recommendations of the board.

[2] Represented on the board by Mr. Paul Bailey.

CONTENTS

	Page
1. Introduction	1
2. Description of basin	2
3. Power and irrigation possibilities in Stanislaus Basin	6
4. Conclusions and recommendations	22

TABLES

No. 1. Mean monthly flow of North Fork Stanislaus River at intake of Utica Conduit	25
No. 2. Stanislaus River seasonal run-off data	25
No. 3. Estimate of ultimate power that can be economically developed on North Fork Stanislaus River	27
No. 4. Estimate of storage required to operate system of Utica Mining Co. at present capacity on a reasonable load factor	27
No. 5. Details of North Fork Stanislaus River projects	28
No. 6. Details of Stanislaus River projects	29

ILLUSTRATIONS

PLATE 1. General map of California	Frontispiece.
2. Map of Stanislaus watershed	2
3. Profile of projects on North Fork of Stanislaus River	5
4. Profile of projects on Middle and South Forks of Stanislaus River	6
5. Profile of projects on Stanislaus River	7
6. Spicers Meadows Dam site	11
7. Ramsey Dam and Reservoir site	13
8. Beardsley Flat Dam and Reservoir site	15
9. Robinsons Ferry Dam site	17
10. Melones Dam site	18
11. Black Creek Dam site	20

1. INTRODUCTION

1. This board was constituted on May 25, 1923, to study and report on problems connected with the Trinity, the American, and the Stanislaus Rivers in California. Reports on the two first mentioned having been rendered, this report deals with the Stanislaus River, in regard to which the following instructions were received:

North Fork of Stanislaus River.—The commission has before it an application contemplating the creation of storage on a tributary of the North Fork of the Stanislaus River for use in connection with existing canals and power plants in the vicinity of Angels and Murphy. It appears probable that a development such as proposed is not economical and might seriously interfere with the complete development of the stream. The present diversions through the old mining ditch can not be changed because irrigation rights have grown up in the vicinity of Murphy and Angels which can not be set aside. An increase in the amount of water taken through this ditch might set up new rights and make it impracticable to return the waters to the stream in a manner which would provide for the best utilization of the power. It is desired that the board review this situation, investigate the various interests involved, and report to the commission what plan of development will, in its judgment, be best suited to make a complete utilization in the public interest.

2. The board is composed of representatives of the Departments of War, Interior, and Agriculture, to which is joined a representative of the State of California, within which State the basin of the Stanislaus is situated.

3. The first meeting of the board was held in San Francisco on July 13, 1923. Since that time other meetings have been held by the full board in San Francisco.

4. Field examinations were made by the board in the latter part of September, 1923, later supplemented by special investigations made by the different members at various times. A survey was made of the Robinsons Ferry and Black Creek Dam sites in the foothill reaches of the Stanislaus River by members of the United States Forest Service. Information was obtained in regard to the Beardsley Flat and Melones Dam and Reservoir sites from Mr. R. E. Hartley, chief engineer of the Oakdale Irrigation District. The Pacific Gas & Electric Co. kindly furnished considerable information in regard to the area irrigated in the foothills of the Stanislaus and Tuolumne watersheds south of the Stanislaus by the Phoenix system of the Sierra & San Francisco Power Co., which is operated by them under lease. Messrs. Walter L. Huber, consulting engineer of the city of San Francisco and E. S. McCurdy, mining engineer, furnished

information in regard to the system of the Utica Mining Co., which develops power and furnishes water for domestic, irrigation, and mining purposes in the foothills on the Stanislaus and Calaveras watersheds north of the Stanislaus River.

5. This board deemed it necessary in following the commission's instructions to give consideration to the main stream and all of its branches. In Part 2 of this report a brief description of the Stanislaus River Basin has been given. Part 3 contains a description of the power and irrigation possibilities of the Stanislaus and estimates of capacities of the power sites on the North Fork. Part 4 contains conclusions and recommendations to the commission covering an outline for a general plan for the most advantageous development of the stream for all uses that can now be forseen.

2. DESCRIPTION OF BASIN

1. The Stanislaus River is a tributary of the San Joaquin, flowing into this stream from the east. (See frontispiece.) It drains about 1,200 square miles of mountainous and valley area in central California, lying between the crest of the Sierras on the east and the San Joaquin River on the west, a distance of approximately 100 miles. The watershed has a width of about 24 miles at the Sierra crest, tapering to about 10 miles at the midpoint, which width it does not exceed to its junction with the San Joaquin River. Plate II shows the river system in detail.

2. The drainage basin of the Stanislaus lies between the Tuolumne watershed to the south and the Little John Creek, Calaveras, and Mokelumne watersheds on the north.

3. The watershed slopes from an elevation of about 10,000 feet at the Sierra crest to about 20 feet at the San Joaquin River. Granite peaks, domes and glaciated basins are typical of the highest area next to the Sierra divide. Below are long, well-timbered ridges, basins and canyons which gradually break into rolling foothills covered with scattering oak timber. Between the foothills and the San Joaquin lie the level lands of the Stanislaus watershed which are within the Sacramento-San Joaquin Basin.

4. The principal tributaries of the Stanislaus are the North and Middle Forks, the latter draining a shed extending back to the main divide. The headwaters of the former are separated from the Sierra crest for a short distance by the Mokelumne shed. These forks unite in the mountainous part of the drainage area at a point about 40 miles from the Sierra crest, forming the Stanislaus River proper which is joined about 6 miles below by the South Fork. The South Fork drainage is separated from the main divide by the watersheds of the Upper Middle Fork and of the Tuolumne River. From the mouth of the South Fork the stream runs through the foothills for a

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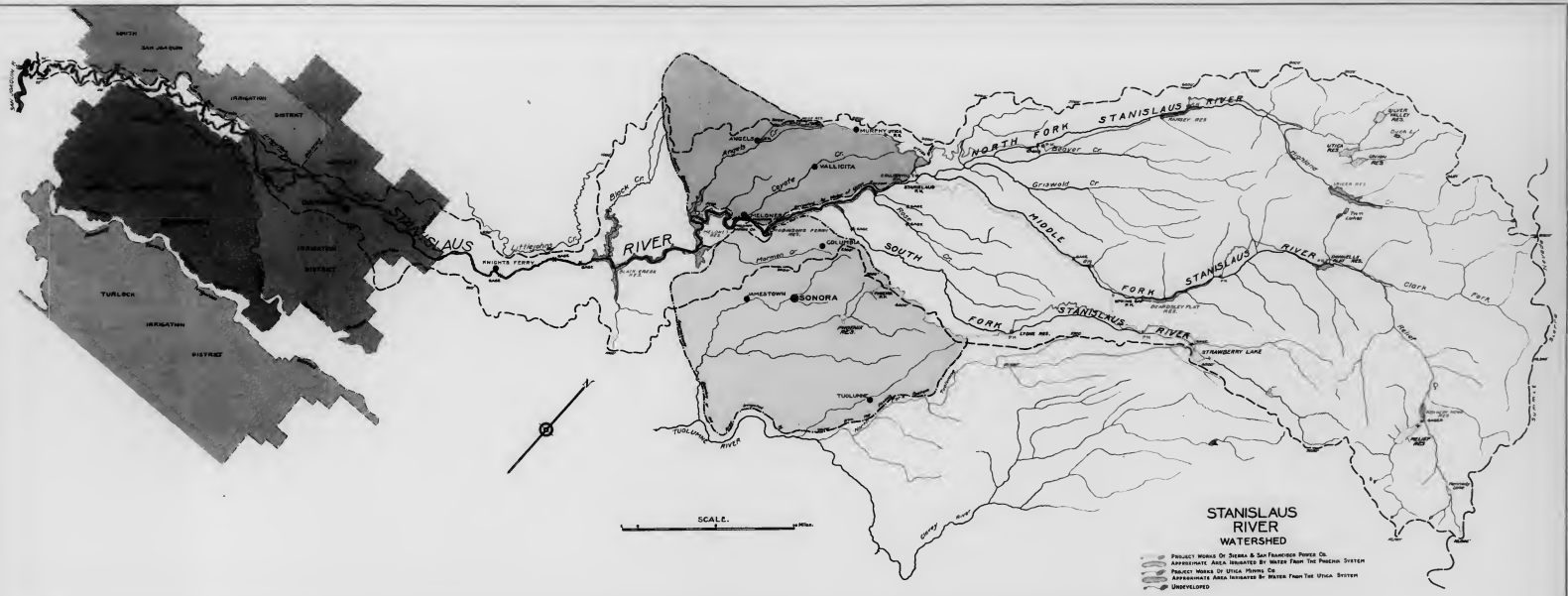
SOUTH SAN JOAQUIN IRRIGATION DISTRICT
TURLOCK IRRIGATION DISTRICT
STANISLAUS RIVER
KNIGHTS FERRY
BIG CREEK
BRUSH CR.
ANGELS CR.
ANGELS
MURPHYS
VALLECITO
CALAVERAS RIVER
HELLS HOLE
HUNTERS RES.
CLARKS FORK RES.
RAMSHORN FORK RES.
COLUMBIA
MARTINS CR.
JAMESTOWN
SONORA
TUOLUMNE RIVER
TUOLUMNE
SCALE.
NORTH FORK STANISLAUS RIVER
BEAVER CR.
GRISWOLD CR.
MIDDLE FORK STANISLAUS RIVER
SOUTH FORK STANISLAUS RIVER
BEAR CR.
BOOTJACK
STRAWBERRY LAKE
CLARK FORK
CLARK FORK RES.
UTICA RES.
UTICA DAM
UTICA LAKE
DUCK LK.
DUCK LK. RES.
CRYSTAL SPRINGS RES.
TWIN LAKES
TWIN LAKES RES.
CLOTH
CLOTH RES.
BEAR RES.
BEAR RIVER
BEAR RIVER RES.
BOWMAN
BOWMAN RES.
SPICER MEADOW RES.
SPICER MEADOW RESERVOIR
SILVER LAKE
SILVER LAKE RES.
DARDANELLE
DARDANELLE RES.
STRAWBERRY
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CHERRY
CHERRY RIVER
STANISLAUS
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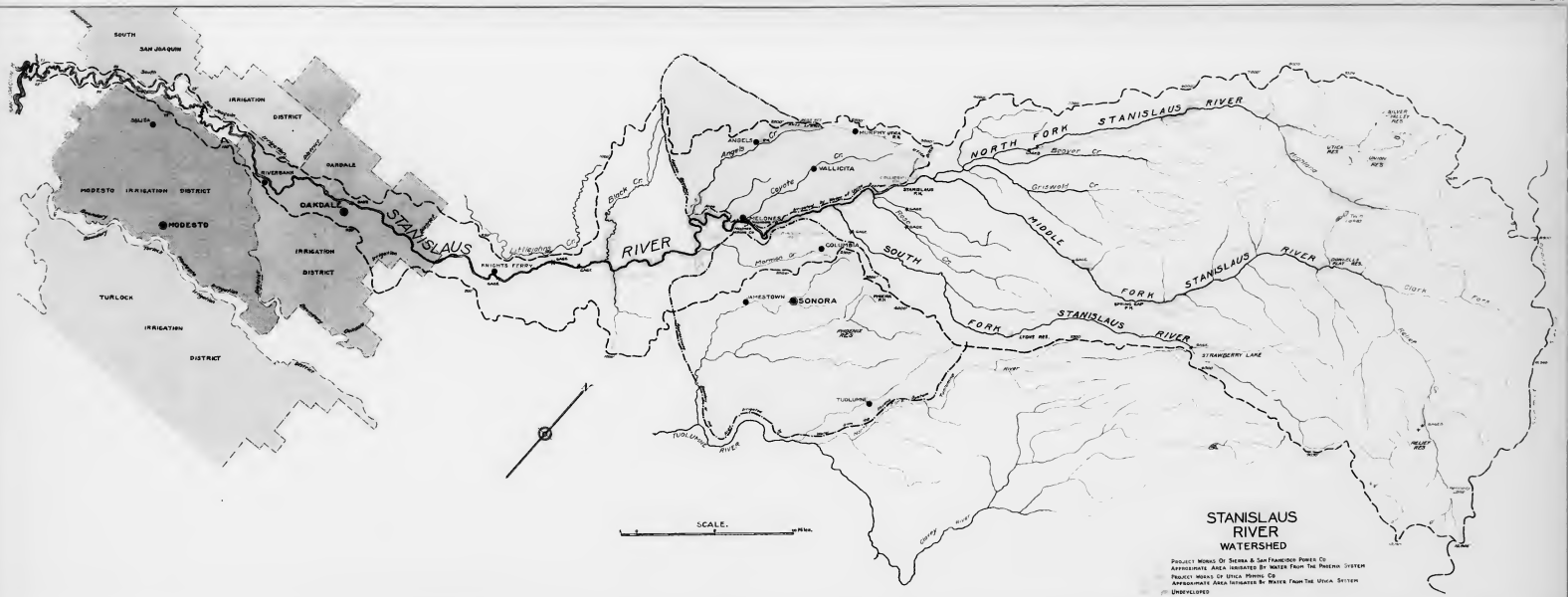
STANISLAUS

INTENTIONAL SECOND EXPOSURE

PLATE 2



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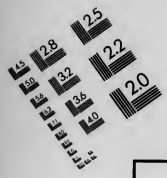

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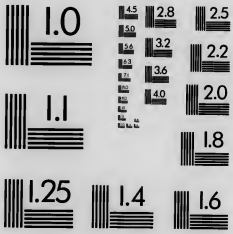

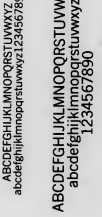

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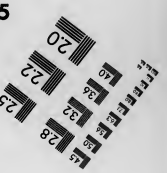

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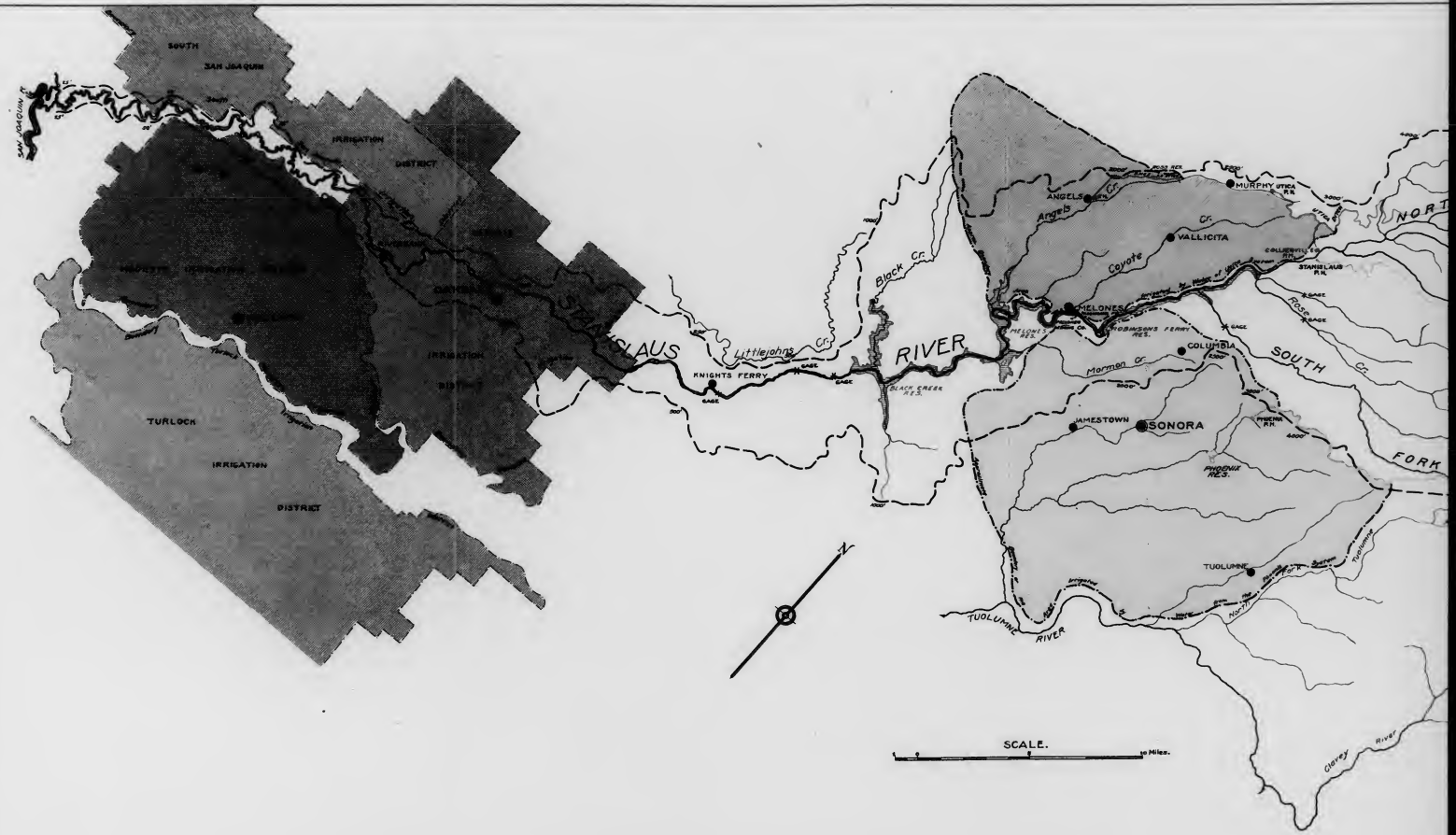
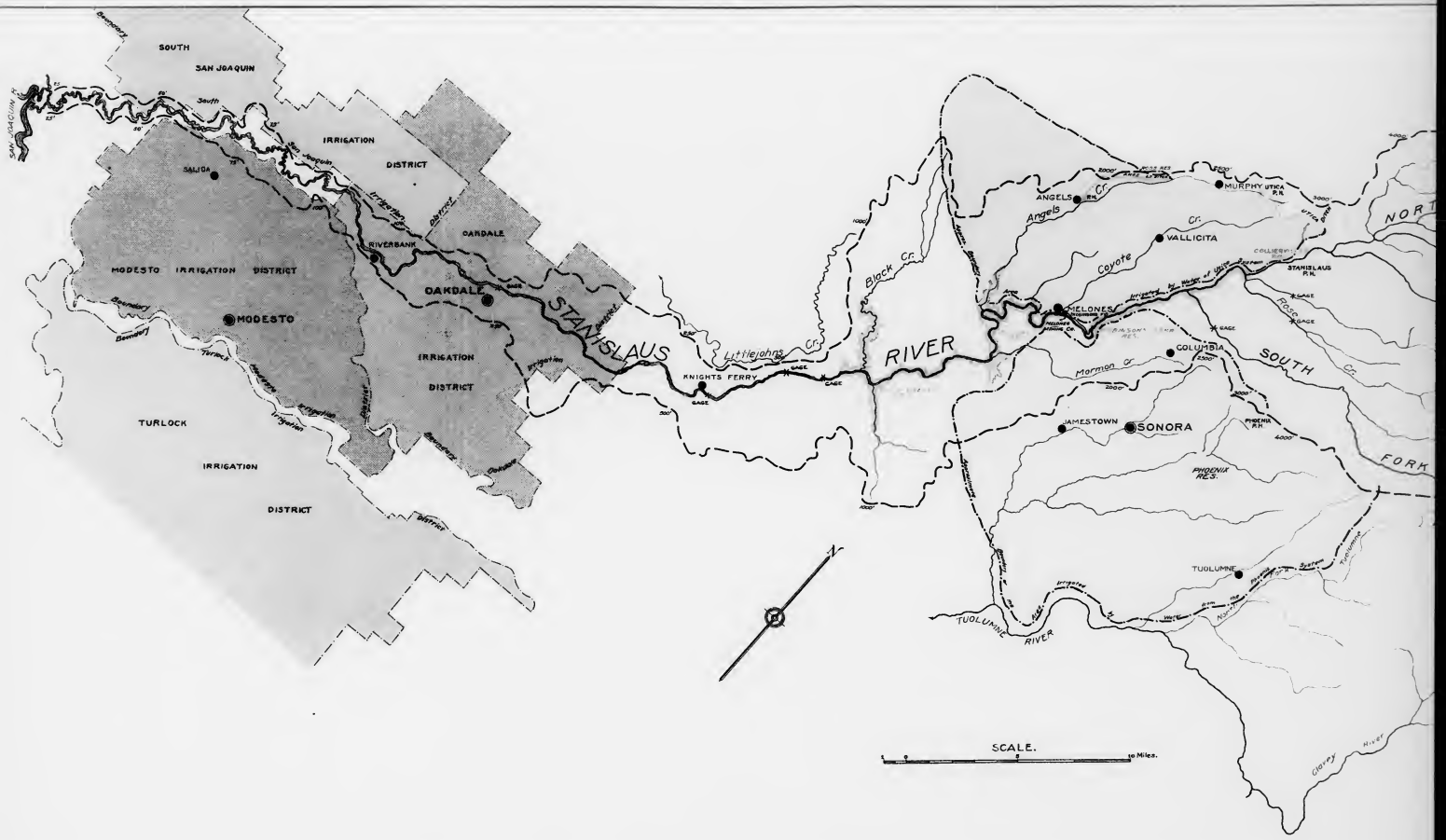
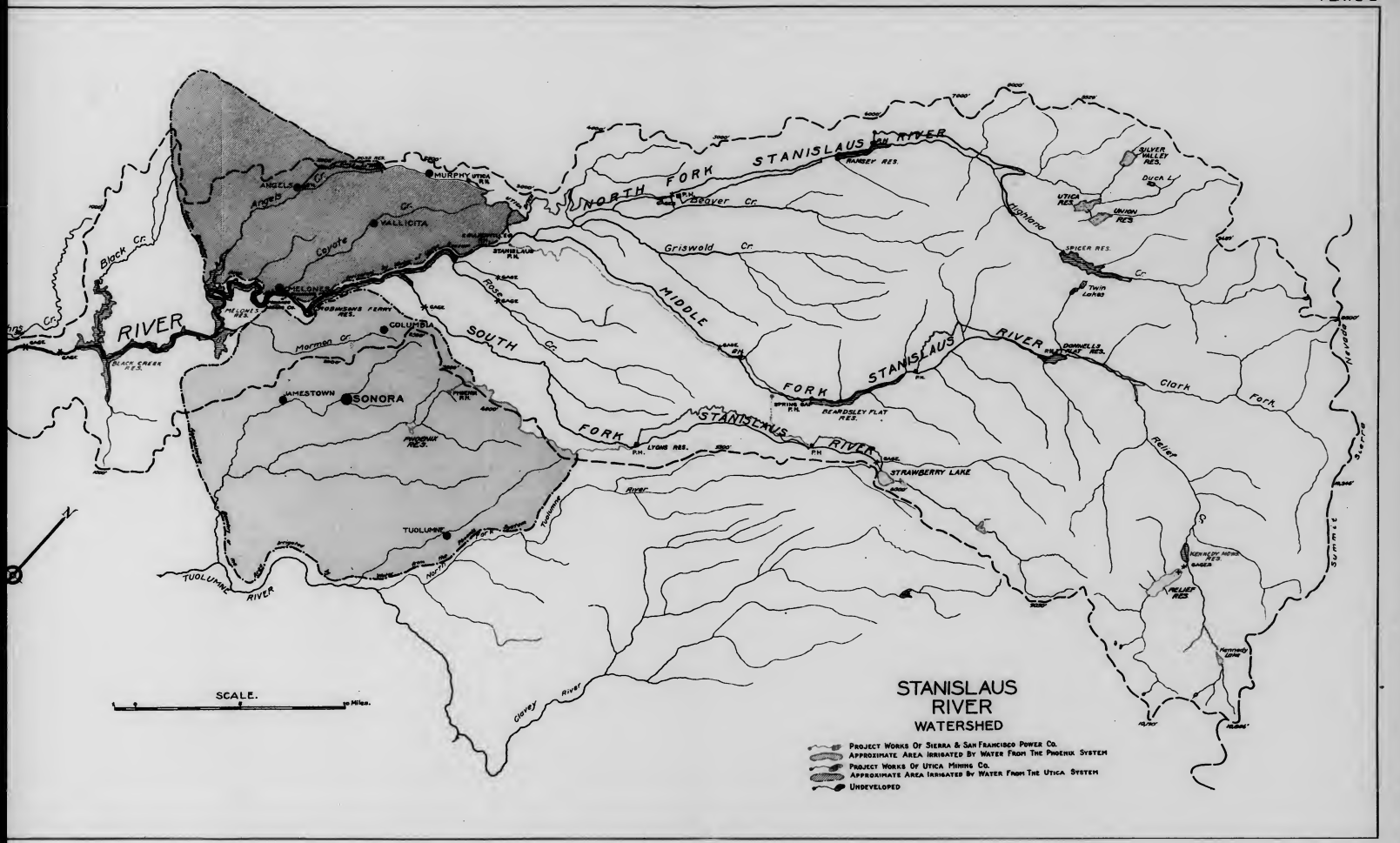

SOUTH
SAN JOAQUIN
IRRIGATION
DISTRICT
TURLOCK
IRRIGATION
DISTRICT
STANISLAUS
RIVER
Littlejohns Cr.
KNIGHTS FERRY
Black Cr.
BLACK CREEK RES.
ANGELS
Angels
Cr.
MURPHY
VALLICITA
Coyote
Cr.
MELONES
ROBINSONS FERRY
COLUMBIA
Mormon Cr.
SOUTH
Cr.
JAMESTOWN
SONORA
FORK
PHOENIX RES.
TUOLUMNE
TUOLUMNE RIVER
SCALE.
Miles.

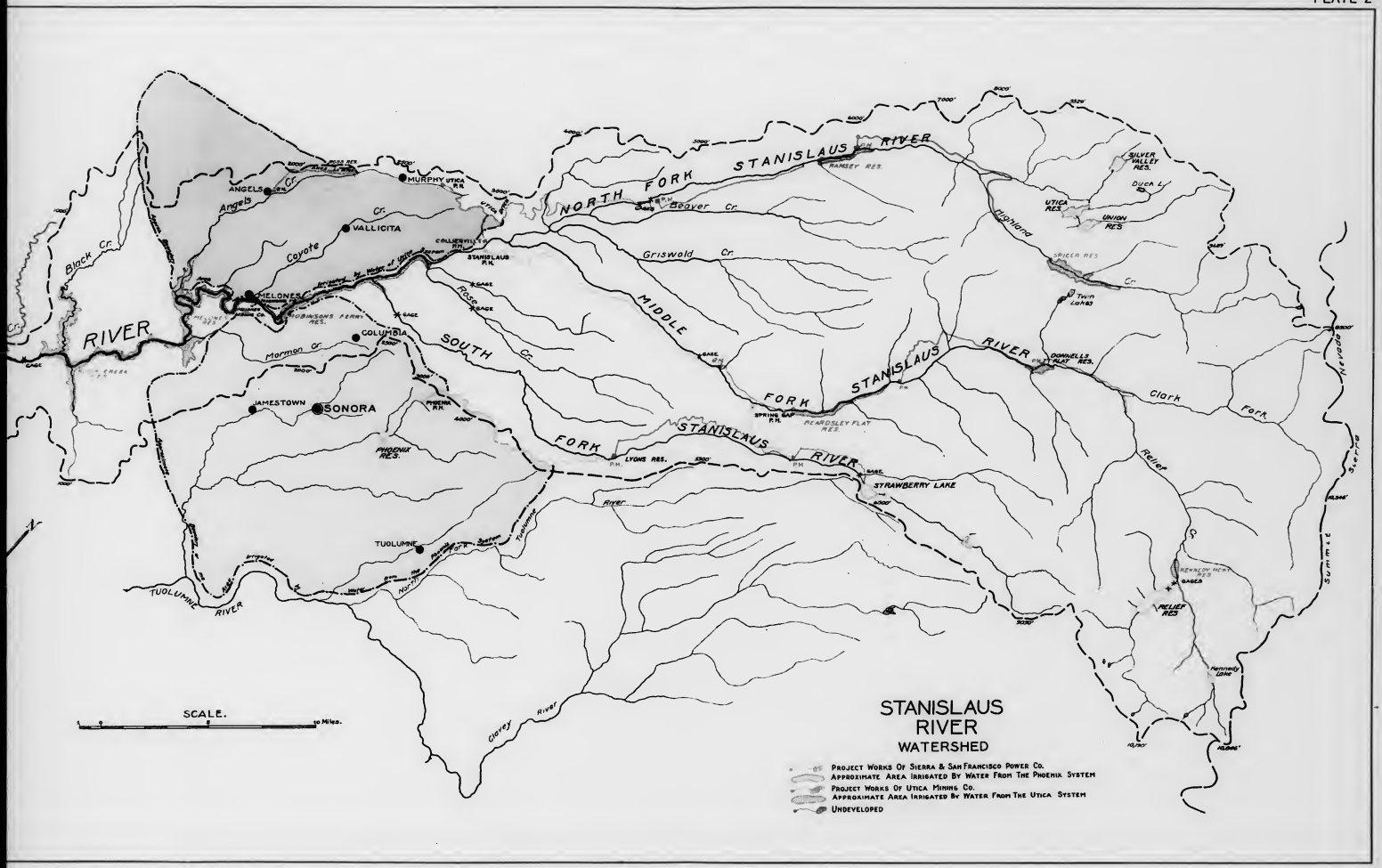
INTENTIONAL SECOND EXPOSURE




STANISLAUS
RIVER
WATERSHED
SCALE.
Miles.
PROJECT WORKS OF SIERRA & SAN FRANCISCO POWER CO.
APPROXIMATE AREA IRRIGATED BY WATER FROM THE PHOENIX SYSTEM
PROJECT WORKS OF UTICA MINING CO.
APPROXIMATE AREA IRRIGATED BY WATER FROM THE UTICA SYSTEM
UNDEVELOPED
NORTH FORK STANISLAUS RIVER
MIDDLE FORK STANISLAUS RIVER
SOUTH FORK STANISLAUS RIVER
TUOLUMNE RIVER
MERCED RIVER
Angels Cr.
Black Cr.
Coyote Cr.
Mormon Cr.
Beaver Cr.
Griswold Cr.
Rose Cr.
Highland Cr.
Clark Fork
Relief Cr.
Summit
MURPHY
UTICA RR.
ANGELS
WALLICITA
MELONES
MELONES RES.
ROBINSONS FERRY
COLUMBIA
JAMESTOWN
SONORA
TUOLUMNE
STANISLAUS RR.
SPRING GAP RR.
RAMSEY RES.
SILVER VALLEY RES.
DUCK L.
UTICA RES.
UNION RES.
SPICER RES.
TWIN LAKES
DONNELLS RES.
READSLEY FLAT RES.
LYONS RES.
PHOENIX RES.
STRAWBERRY LAKE
KENNEDY MEMO RES.
RELIEF RES.
HUNTINGTON LAKE
BLACK BEAR RES.

INTENTIONAL SECOND EXPOSURE

PLATE 2



distance of about 35 miles and thence across the level Sacramento-San Joaquin Basin for about 25 miles further to its junction with the San Joaquin.

5. The principal activities of the mountainous section are mining, lumbering, and grazing. There are practically no towns, through numerous summer resorts and summer camp sites are within this section.

6. The principal towns of the foothills are Angels, Vallecito, Murphy, and Columbia. There is some farming in scattered areas in this section.

7. The principal town on the valley floor is Oakdale. The chief activity is farming.

8. The foothill areas are irrigated in patches where water is available. Old mining ditches, now used for power and irrigation, in most cases are the principal means of supply. The principal foothill areas under irrigation are in the vicinity of Murphy and Angels where water is supplied from the North Fork by the Utica Power & Mining Co., and in the vicinity of Columbia where the supply is obtained from the Phoenix system of the Sierra & San Francisco Power Co., taking water from the South Fork. The total area irrigated in the foothills is about 1,700 acres. The irrigation service is very expensive on account of the great length of supply ditches and the isolated location of each tract. Some South Fork water is carried by the Phoenix ditch across the divide into the Tuolumne drainage area around the town of Sonora, where expansion of irrigation is possible. Such expansion must look to the South Fork of Stanislaus for a supply rather than to the Tuolumne, since practically all water of the Tuolumne drainage is appropriated by the Turlock and Modesto irrigation districts, the city of San Francisco, and others.

9. Most of the valley area lies within the boundaries of the Oakdale, South San Joaquin, and Modesto irrigation districts. The first two districts depend upon the Stanislaus River for their irrigation supply, whereas the Modesto district gets its supply from the Tuolumne. The irrigable area within the boundaries of the first two districts is about 125,000 acres, of which about 20,000 acres are now being irrigated in the Oakdale district and about 54,000 acres in the South San Joaquin district. These districts divert water from the Stanislaus at the Goodwin Dam, near Knights Ferry They have a joint ditch capacity and water right in the stream of 1,785 second-feet and divert the entire flow up to the capacity of their ditches when needed and available. The river flow is inadequate for irrigating their entire area and in very dry years is even insufficient for irrigating the portion of the districts now under cultivation. The districts have considered developing several storage sites on the Stanislaus shed in order to obtain an additional supply, among which

is the Melones site which can be developed to a capacity of 100,000 acre-feet. The total feasible storage on the main stream may be 370,000 acre-feet, far in excess of probable irrigation needs of these districts.

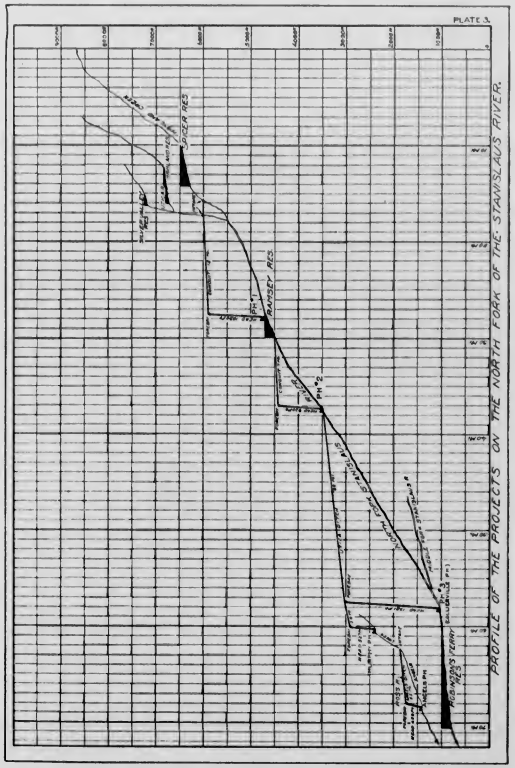
10. Run-off records have been kept at points in the vicinity of the shed at elevations varying from 5,800 feet at Bear Valley Reservoir in the Mokelumne drainage, to 23 feet at Stockton. Studies made by Charles H. Lee and others, indicate that the highest precipitation for this section occurs between elevations 4,000 and 6,000 feet, above which precipitation begins to decrease. A precipitation map of this portion of the Sierras prepared by Walter L. Huber, consulting engineer of the city of San Francisco, indicates a maximum precipitation of about 55 inches about 20 miles west of the main Sierra divide, which is in a general way the location of the 6,000-foot contour, decreasing to about 50 inches at the main Sierra divide on the east, and to about 40 inches at the beginning of the foothills on the west. The precipitation in the foothills varies from about 40 inches at the eastern or upper end to about 15 inches at the Sacramento-San Joaquin Valley floor on the west. Precipitation in the part of the Stanislaus watershed in the Sacramento-San Joaquin Basin is about 10 inches. Irrigation is necessary for the successful cultivation of most crops both in the foothills and on the valley floor. Plate 5 of Bulletin No. 6, Department of Public Works, State of California, entitled "Irrigation of California Lands," shows a net irrigation requirement of 1.5 acre-feet per acre in the foothills of the Stanislaus drainage and 2 acre-feet per acre on the valley floor.

11. The Stanislaus River has been gauged since May, 1902, at Knights Ferry at approximate elevation 175 feet. This is a short distance above the point where the stream leaves the foothills. The drainage area above this station is 983 square miles. The mean annual run-off during the period of record is 1,275,000 acre-feet, equivalent to 1,297 acre-feet per square mile. The mean annual for the period 1871–1921 is estimated by the State (Bulletin No. 5) at 1,376,000 acre-feet, with a maximum in 1889–90 of 3,580,000, and a minimum in 1876–77 of 408,900 acre-feet, these amounts being equivalent respectively to average seasonal flows of 1,885, 4,800, and 560 second-feet. (See Table No. 2.)

12. Stream-flow records have been kept at the intake of the Utica Mining Co's. conduit on the North Fork of the Stanislaus River at about elevation 3,347 feet, since July 14, 1914. (See Table No. 1.) This station is about 8 miles above the junction with the Middle Fork.

13. Stream-flow records have been kept on the Middle Fork of the Stanislaus at Sand Bar Flat near the intake of the Stanislaus power plant since September 1, 1905, at an approximate elevation of 2,700 feet.

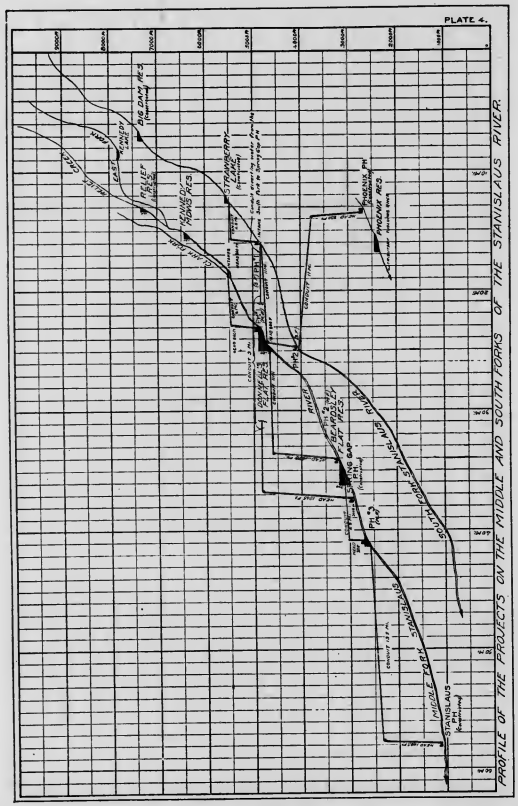
14. Stream-flow records were kept on the South Fork of the Stanislaus at Strawberry, Calif. (elevation 5,200 feet, drainage area 54 square miles), from October 20, 1911 to January 31, 1917.



15. Stream-flow records were kept on Relief Creek, a tributary of the Middle Fork of the Stanislaus, below Relief Reservoir, from October, 1910, to September 30, 1917, at approximate elevation 7,300 feet, with tributary drainage area of approximately 29 square miles.

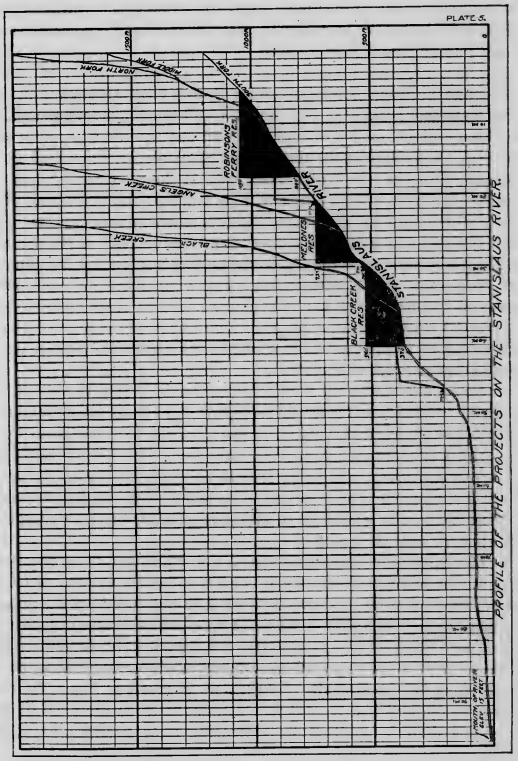
3. POWER AND IRRIGATION POSSIBILITIES IN STANISLAUS BASIN

1. The potential power of the Stanislaus River and its three forks may be developed as shown on stream profile Plates Nos. 3 to 5.



Principal data regarding North Fork power development and main stream storage possibilities are shown in Tables Nos. 5 and 6. This power has been partly developed, the Utica Mining Co. having two

power houses on Angels Creek utilizing water from the North Fork, and the Sierra & San Francisco Power Co. having two power plants on the Middle Fork, the upper utilizing water from the South Fork and releasing it into the Middle Fork, and the lower utilizing both



South and Middle Fork water. This company also has one plant releasing water which is diverted from the lower reaches of the South Fork into the Tuolumne drainage.

2. The Utica Mining Co. furnishes power for mining and domestic use in the vicinity of Angels, Murphy, and Vallicita. The system of

the Sierra & San Francisco Power Co. is under lease to the Pacific Gas & Electric Co. and is connected by a transmission line to the system of this company.

3. There is one developed power project on the Stanislaus below the junction of the three main forks, this being the project of the Melones Mining Co., at Melones, Calif., from which power is leased to the Pacific Gas & Electric Co.

4. There are two undeveloped power possibilities on the South Fork—one between Strawberry and Spring Gap diversion, and the other between Spring Gap diversion and Phoenix diversion. There are three undeveloped power projects on the Middle Fork above the diversion of the Stanislaus plant of the Sierra & San Francisco Power Co., and three on the North Fork, two of them being between the storage reservoirs of the Utica Mining Co. on the headwaters of the North Fork and the diversion point of their Murphy plant. The third would involve dropping water from the conduit of the Murphy plant back to the Stanislaus in so far as it is not needed for domestic use, irrigation, and mining, and using it through the company's proposed Collierville power plant under higher head, instead of in the present development at Angels. The water thus becoming available would be reinforced and regulated by additional storage on the headwaters at Spicer Meadows.

5. All of the foregoing projects develop heads by means of long conduits. There are three undeveloped sites on the main Stanislaus River below the Stanislaus plant of the Sierra & San Francisco Power Co., which would be developed by high dams with considerable storage above each dam. In each case the power house would be located either immediately or not far below the dam. The storage developed at these three sites would be of sufficient quantity to be valuable for irrigation as well as power.

6. The developed storage of the Utica Mining Co. on the North Fork of the Stanislaus consists of the Silver Valley, Union, and Utica reservoirs, with total capacity of 9,000 acre-feet and a total tributary drainage area of 29.5 square miles, all located inside a radius of about 2½ square miles between elevations 6,800 and 7,300 feet. With the exception of the Utica Reservoir they are developed to as great a capacity as is economically feasible or as great as their tributary drainage area will justify. It will ultimately be economical to raise the Utica dam 5 feet thereby increasing its capacity about 2,000 acre-feet.

7. The conduit of the Utica Mining Co. (capacity of 88 second-feet) diverts from the North Fork of the Stanislaus River at approximate elevation 3,347 feet, which is 22 miles below the Utica reservoir, the lowest of the group of reservoirs described in the preceding paragraph.

8. Highland Creek, which is the chief tributary of the North Fork, joins the North Fork from the south at a point 17 miles above the intake of the Utica conduit. The Spicers Meadow Reservoir site is located on this creek at a point about 6 miles above its mouth, the proposed dam being at stream-bed elevation of 6,380 feet. It is the reservoir covered by the commission's application No. 95, filed by the Utica Mining Co. and referred to specifically in the instructions to this board.

9. The conduit of the Murphy project of the Utica Mining Co. is located on the north bank of the North Fork and is 22.6 miles in length from the intake on the North Fork to the penstock at the power house. It is partly in box flume and partly open ditch, with grade of 15 feet per mile. The elevation of the intake of the penstock is 2,941 feet. The ditch was originally built for mining purposes and loses more grade than is customary for present-day construction. The power house is a masonry building containing two 750 K.v.a. generators. The head from penstock to tailrace is 527 feet. Water is released into Angels Creek from nozzles at elevation 2,414.

10. As stated in section 4, the company has considered the possibility of dropping all water not needed for mining, irrigation, and domestic purposes in its present system, and water gained by additional storage, from a point on its conduit located approximately 2½ miles above the intake of present penstocks of the Murphy plant to a proposed power house, which has been designated the Collierville project, to be located on the Stanislaus River about ¾ mile above the Stanislaus plant of the Sierra & San Francisco Power Co. Water would be released into the river at elevation 1,094 feet. A head of 1921 feet from fore bay to nozzles would be developed, and if the grade of present ditch were reduced it is estimated by engineers of the Utica Mining Co. that this head could be increased to 2,100 feet.

11. From the Murphy plant the water now runs down Angels Creek. A large part of it is used for irrigation, mining, and domestic purposes at and in the vicinity of Murphy, Vallecito, and Angels, which have populations of 563, 160, and 941, respectively.

12. A total of 1,400 acres is irrigated by the system, including about 84 acres in the Calaveras drainage. The company is obligated to supply for mining and irrigation purposes during the irrigation season the following peak demands.

	Second-feet
Irrigation	20
Mines	37.45
Total	57.45

This does not include domestic water for the towns mentioned. When the Utica mine is operating 30 second-feet are used for the

development of mechanical power at this mine (included above under the head of mining). When not in operation this water continues to the Angels power house referred to in the succeeding paragraph. Mechanical power developed hydraulically at the Utica mine fits in better with the system than would an equivalent electrical load on account of the large load of the mine hoists coming suddenly on and off. Such a load on a small electrical system as that of the Utica Mining Co. is very undesirable. Also such a load on any system would entail high rates for power used on account of the low load factor.

13. The irrigated tracts under the Utica system are widely separated and the total area susceptible of successful agricultural development is very limited. The water leaving the Murphy power house, not used for domestic or irrigation purposes in the vicinity of Murphy or Vallicita, is diverted from Angels Creek at approximate elevation 1,875 feet, at a point 3 miles below the Murphy power house; thence it is conducted through 5.5 miles of conduit, of which 4.4 miles is open ditch and 1.1 miles is wooden flume, to a fore bay at elevation 1,842, with capacity of 245 acre-feet. En route from diversion on Angels Creek to for ebay the conduit passes through the Ross reservoir with capacity of 240 acre-feet. From the fore bay water goes by pipe lines to Angels, where a part of it, when not used to operate the hoists at the Utica mine, is run through the Angels power house in which are installed a 250-kilowatt and a 323-kilowatt generator. The static head at the plant from fore-bay elevation 1,842 feet is 450 feet. The remainder of the water is used for mining, domestic, or irrigation purposes. Water is released from the power house into Angels Creek and flows back into the Stanislaus above the intake of the Oakdale and South San Joaquin irrigation districts, which is the first large irrigation diversion on the river. Some water is used for irrigation between Angels Camp and the mouth of Angels Creek.

14. Summarizing, the total electric installation at Murphy is 1,500 kilowatts and at Angels is 573 kilowatts, this being used only when the mines do not require hydraulic power water. The heads are, respectively, 527 and 450 feet. For any part of the power water which can be released through the proposed Collierville plant the head into the Stanislaus would be 1,921 feet at present grade of flume and 2,100 feet at proposed enlarged flume grade.

15. The water thus to be released to the Collierville plant would not in itself be sufficient to justify this new construction, which, however, would become practicable in connection with additional upper storage, which could also be used by proposed power plants higher up the stream.

16. Between the upper reservoirs on the North Fork of Stanislaus River, elevation about 6,000 feet, and the Stanislaus power plant on the main stream at approximate stream-bed elevation of 1,050 feet,

it is believed to be economically feasible to develop a total head, fore bay to tailrace of 4,111 feet, in three power drops. It will also be practicable ultimately to increase the storage on the headwaters of the North Fork by the construction of a dam 150 feet high to ele-

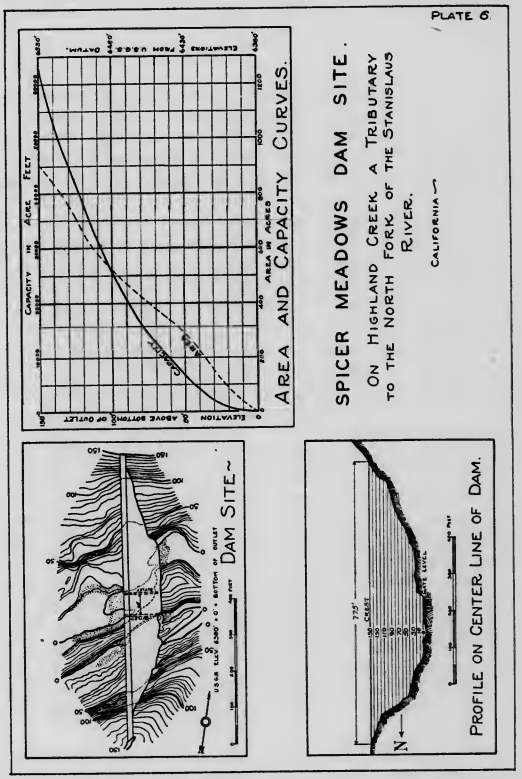


PLATE 6.
SPICER MEADOWS DAM SITE.
ON HIGHLAND CREEK, A TRIBUTARY TO THE NORTH FORK OF THE STANISLAUS RIVER, CALIFORNIA
AREA AND CAPACITY CURVES.
DAM SITE
PROFILE ON CENTER LINE OF DAM.

vation 6,530 feet at the Spicers Meadow Reservoir site, which would flood an area of 903 acres and would make available 63,000 acre-feet of storage. (See Plate 6 for contour map of dam site, and area and capacity curve of reservoir.) The dam would be about 800 feet long

on the crest. Such height would require four auxiliary dams of the following dimensions:

	Crest length	Height		Crest length	Height
	Feet	*Feet*		*Feet*	*Feet*
No. 1	84	20	No. 3	206	19
No. 2	122	27	No. 4	228	36

The abutments and foundations for all the dams appear to be excellent. The formation is granitic, bedrock being in evidence.

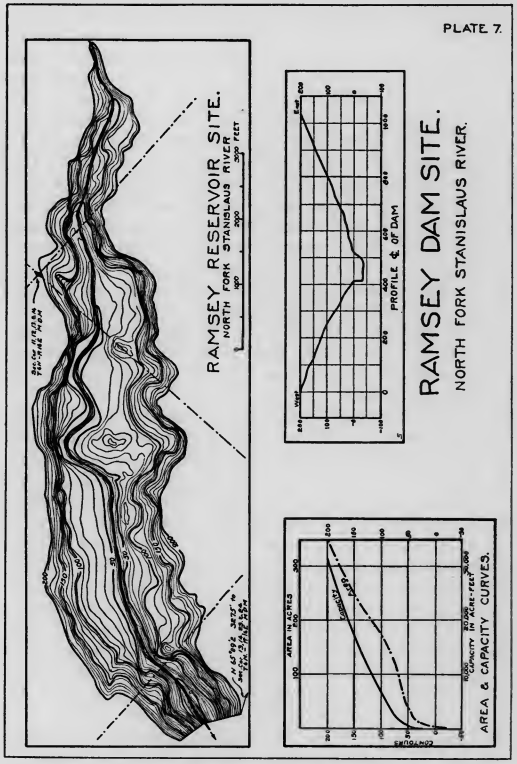
17. The upper or No. 1 power site on the North Fork would probably divert from Highland Creek at elevation 6,000 feet at a point about 3½ miles below the Spicers Meadow Dam to a conduit, which would have to be covered on account of the altitude. The conduit would run along the north side of Highland Creek and thence to a diversion on the main North Fork at a point about 4 miles below the Utica Reservoir; thence it would continue down the north side of the main North Fork for a distance by stream of approximately 9 miles from the diversion on Highland Creek, making the total length of conduit approximately 12 miles; thence the water would be dropped through the penstock to a power house located on the North Fork, returning the water to the North Fork at a point 6½ miles below the mouth of Highland Creek, at approximate elevation 4,750 feet. The static head from fore bay to tailrace would be approximately 1,130 feet.

18. At a point about 2 miles below the No. 1 power-house site on the North Fork of the Stanislaus, at stream bed elevation 4,500 feet, is the Ramsey Meadows Dam site. (See Plate No. 7.) This site may ultimately be suitable for a dam 235 feet high, which would store approximately 32,000 acre-feet of water, having a crest length of approximately 1,040 feet. Plate No. 7 shows an area and capacity curve for the reservoir and a cross section and plan of the dam site. The formation at this site is granitic, bedrock being exposed. The section widens very rapidly as the elevation increases at the Ramsey site, for which reason a dam 235 feet high may not prove economical. For the purpose of power computations on the North Fork of the Stanislaus River, the capacity of this reservoir has been taken in this report as 16,600 acre-feet, which would require raising the water 185 feet.

19. The conduit of the North Fork No. 2 power project would probably be located on the south side of the stream on account of topography and would lead from the Ramsey Meadow Dam at elevation approximately 4,500 feet for a distance of about 8 miles to a power house to be located on the North Fork at a point just above the present intake of the Utica conduit. Water would be returned

to the North Fork at elevation 3,360 feet. A static head, fore bay to tailrace, of approximately 1,060 feet would be developed.

20. A full utilization of the power possibilities of the stream with the development of the known feasible storage sites above would



require the enlargement and reconstruction of the Murphy conduit as far as the point of drop to the Collierville power house, which has been designated the No. 3 project. The enlargement would be from its present capacity of 88 second-feet to about 410 second-feet if

suitable fore bay can be found. If not, additional capacity would be necessary to provide for the variations in the system load necessary to be cared for in this plant.

21. The investigations of the board indicate that an average of about 50 second-feet may be furnished by this company for domestic, irrigation, and mining purposes in the territory served by the present system. Allowing this quantity of water to continue to the Murphy power house, there would still have been available for diversion to the proposed Collierville (No. 3) power house an average of 231 second-feet through the project during the period from July, 1917, to June, 1921, as shown by Table No. 3 The static head at the No. 3 power house, fore bay to tailrace, would be 1,921 feet, water being diverted from the Utica conduit at elevation 3,015 feet and released from nozzles to the Stanislaus River at elevation 1,094 feet. Since, as explained in paragraph 10, part 3, this head may be increased to 2,100 feet, the higher head was used in the computations in Table No. 3. The average capacity of this plant during this period would be 38,800 horsepower according to these figures.

22. For the sake of completeness, a presentation of some data regarding power possibilities on the other forks is desirable. It will be possible to develop a total fall on the Middle Fork of the Stanislaus River of at least 2,330 feet in three projects above the diversion of the Stanislaus plant of the Sierra & San Francisco Power Co., which is at elevation 2,704 feet.

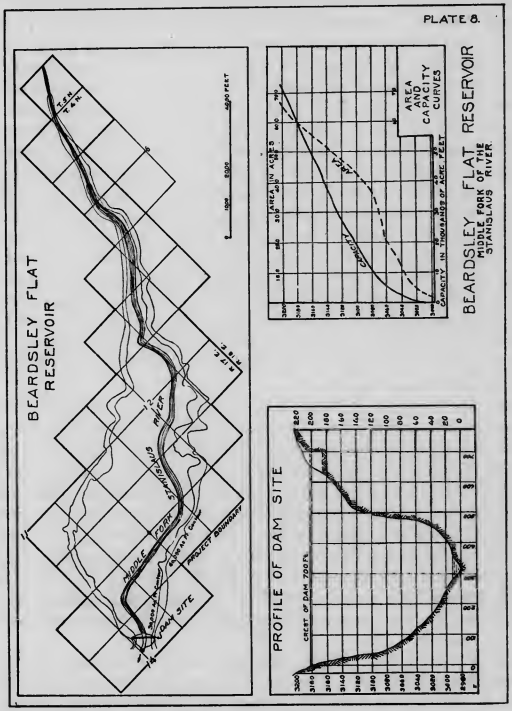
23. The upper project would divert at elevation 5,500 feet from the Clarks Fork and the Middle Fork just above their junction to a 6-mile covered conduit on the north bank of the river, returning water to the stream at elevation approximately 4,900 feet. A head from fore bay to tailrace of approximately 540 feet would be obtained.

24. The second project would consist of a dam at the Donnells Flat site (stream-bed elevation 4,610 feet), raising the water to elevation 4,900 feet and storing about 50,000 acre-feet, a conduit 10 miles long leaving the reservoir at elevation 4,760 feet, and a power house returning the water to the Middle Fork at elevation 3,190 feet. A head of 1,470 feet, fore bay to tailrace, would be developed. A dam 290 feet high at the Donnells Flat site would be 540 feet long on top.

25. The third project would begin with the construction of a dam at the Beardsley Flat Reservoir site in sec. 14, T. 4 N., R. 17 E., at approximate stream-bed elevation 2,980 feet. (See pl. No. 8.) Surveys made under the direction of R. E. Hartley, chief engineer of the Oakdale irrigation district, indicate that a dam 200 feet high at this site may ultimately be feasible. A dam of this height would impound 62,000 acre-feet. A conduit about 5 miles long would lead from this reservoir at elevation 3,080 feet along the north bank. The power house would return water to the Middle Fork at elevation

2,710 feet, and a head, fore bay to tailrace, of 320 feet would be developed.

26. Below the location of the third power house water is now being used in the Stanislaus plant of the Sierra & San Francisco Power Co., reenforced by South Fork water delivered to the Middle Fork 4 miles



above the company's Middle Fork diversion by the Spring Gap plant of the same company. These plants, together with their stora gone the Middle and South Forks, are described in United States Geological Survey Water Supply Paper No. 493, pages 304 to 318.

27. It will ultimately be desirable to develop at least one project on the South Fork above the Spring Gap diversion which will take

the water from the Strawberry Reservoir, already constructed, through a conduit about 3.5 miles long to a power house, returning the water to the South Fork at the intake of the Spring Gap plant. A drop of 660 feet, fore bay to tailrace, could be developed.

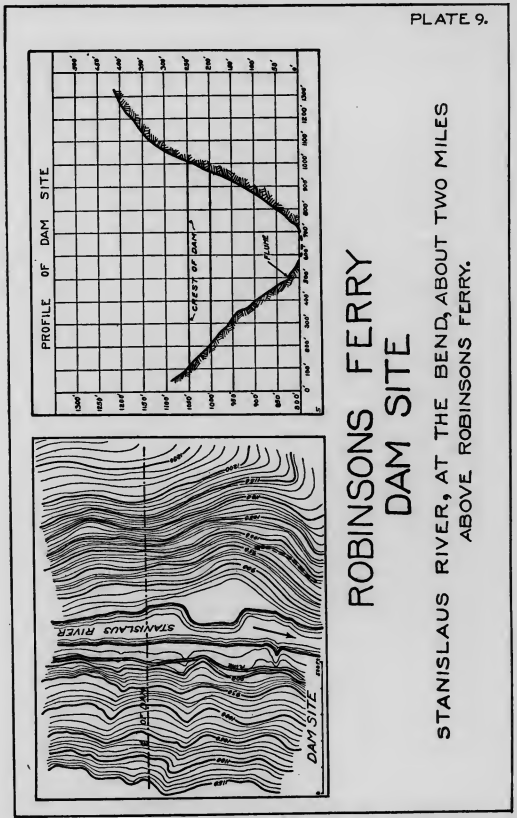
28. The Phoenix plant of the Sierra & San Francisco Power Co. (also described in Water Supply Paper No. 493) diverts from the South Fork at a point about 9 miles below the Spring Gap diversion, the unused fall between these two points being about 800 feet. It may ultimately be desirable to utilize this fall. A head of 690 feet, fore bay to tailrace, could be developed by about 11 miles of conduit.

29. There is a fall of 875 feet in the Stanislaus River from the stream bed at the Stanislaus power house, approximate elevation 1,050 feet, to Knights Ferry, approximate stream-bed elevation 175 feet. The only use now made of this fall is by the Melones Mining Co., which has a 1,000-kilowatt power plant operating under a head of 64 feet, diverting 10 miles below the Stanislaus power house and returning water to the stream 4 miles lower down, near the town of Melones. For proper development of potential power three dams may be constructed, which topographical sheets of the United States Geological Survey indicate would also create approximately 300,000 acre-feet of storage. This storage would be available for both power and irrigation and be primarily valuable for irrigation. The dams would be respectively at the Robinson's Ferry, the Melones, and the Black Creek sites.

30. The Robinson's Ferry Dam site is about 2½ miles above Robinson's Ferry and 6 miles below the mouth of the South Fork. The dam site with stream-bed elevation of about 800 feet is 1½ miles below the diversion dam of the Melones Mining Co. A dam 250 feet high at this site backing water almost to the Stanislaus plant would probably be feasible. It would be 905 feet long on top, according to a survey made by a United States Forest Service party and according to the United States Geological Survey Big Trees topographic sheet, it would flood 1,500 acres and store 90,000 acre-feet of water. Bedrock appears to be near the surface at the foundations and abutments. See Plate No. 9 for a contour map of the dam site and a cross section of the canyon.

31. The second, or Melones Dam, is on the Stanislaus at a point approximately ¼ mile below the mouth of Mormon Creek in sec. 11, T. 1 N., R. 13 E., which is approximately 15 miles below the mouth of the South Fork and 14 miles along the stream above Knights Ferry. The stream-bed elevation is 540 feet. Plate No. 10 of this report shows an area and capacity curve for the reservoir and cross section and contour map of the dam site. A dam 195 feet high above stream bed, of concrete-arch type, would be 585 feet long on crest, would store approximately 112,500 acre-feet of water, and flood 1,850 acres.

The foundations and abutments are apparently very good. Bedrock of a very solid character is in sight at both abutments. This site is



now being considered for development by the Oakdale irrigation district.

32. The Robinson's Ferry and Melones projects would make useless the present power project of the Melones Mining Co., the first

interfering with the intake and the second with the tailrace. The company's plant consists of a low rock-fill diverting dam about 1½ miles above the proposed Robinson's Ferry Dam, a wooden flume 8 feet wide, about 5 feet high and approximately 4 miles long, and a power house at Melones, Calif. The capacity of the flume is 175 second-feet and the fall about 3½ feet per mile. The static head at

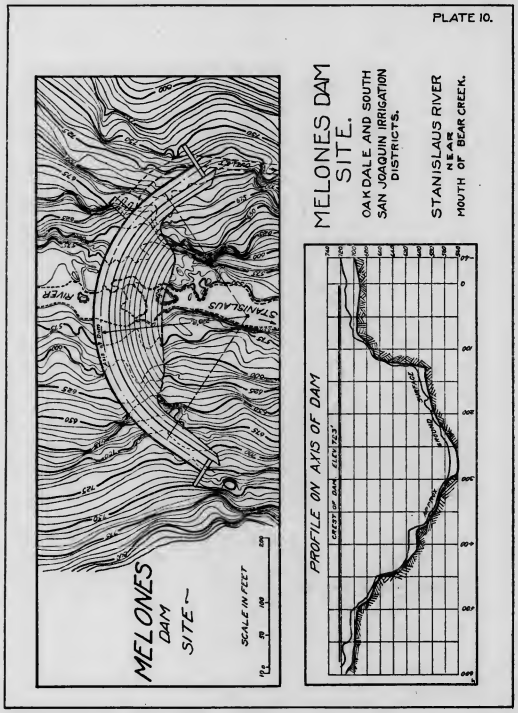


PLATE 10.
MELONES DAM SITE.
OAKDALE AND SOUTH SAN JOAQUIN IRRIGATION DISTRICTS.
STANISLAUS RIVER NEAR MOUTH OF BEAR CREEK.
PROFILE ON AXIS OF DAM
MELONES DAM SITE
SCALE IN FEET

the power house is about 64 feet. The installation is 1,000 K.v.a. The power output is sold under lease to the Pacific Gas & Electric Co. The plant releases water in the stream at elevation approximately 724 feet.

33. The third, or Black Creek Dam site, is located about 2 miles above the Goodwin Dam in secs. 1 and 11, T. 1 S., R. 12 E., on the

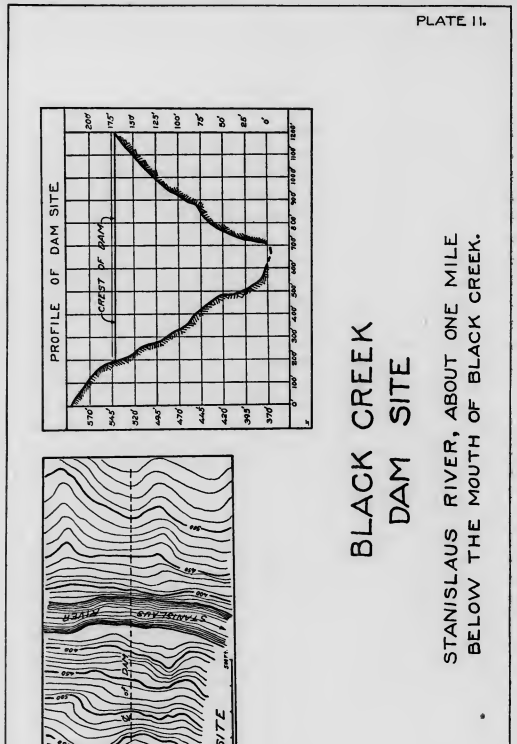
Stanislaus River at a point 5 miles above Knights Ferry at approximate stream bed elevation about 370 feet. A dam 170 feet high at this point would be about 1,030 feet long on top and would flood, according to the United States Geological Survey Copperopolis topographic sheet approximately 1,700 acres and make available 96,000 acre-feet of storage. Bedrock appears to be near the surface at the river bed and abutments. For contour map of the dam site and a cross section of the canyon, see Plate No. 11.

34. The flow of the forks of the Stanislaus River regulated for the benefit of power by the storage reservoirs on the forks and reregulated by the three reservoirs on the main river will make feasible the development of a large power project at the dam below each of these reservoirs. The output will be somewhat seasonal in character assuming the flow to be reregulated primarily for the purpose of irrigation. The power output of the entire stream will, however, fit fairly well with the power demand curve of the San Joaquin Valley on account of the large quantities of power used for irrigation pumping.

35. Estimates of the capacity of power sites have been confined to the sites on the North Fork, in harmony with the instructions to the board. These estimates are shown in Table No. 3. The sites included are the three possible power sites as described in paragraphs 17 to 21. The assumption was made that the present North Fork reservoirs would be increased from the present capacity of 9,000 acre-feet to 11,000 acre-feet, that Spicers Meadows would be developed to 62,000 acre-feet and Ramsey Meadows to 16,600 acre-feet, and that the present Utica conduit would be rebuilt to give a head of 2,100 feet at the proposed Collierville power house and enlarged to a capacity of 410 second-feet. It was also assumed that 50 second-feet of this capacity would proceed to the present Murphy power plant. Under these assumptions the average output during the period considered was estimated as 75,000 horsepower, not including the Murphy plant, and for 90 per cent of the time the output was estimated to exceed 62,000 horsepower.

36. The period considered in power computations is from July, 1917, to June, 1921, four years. An inspection of Table No. 2, which was taken from page 235, "Flow in California Streams," Bulletin No. 5 of the Division of Engineering and Irrigation, Department of Public Works, State of California, shows this period has an average index of wetness of 88. While it is not the lowest period shown by the table, and while accurate estimates in the circumstances are not possible, it is believed that the average output, and also the 90 per cent of the time output for the period 1871 to 1921, may be estimated at 100/88 times the figures mentioned above for the short period 1917–1921. Thus the average output may be placed at 85,000 horsepower and the 90 per cent output limit at 70,000 horsepower.

37. The present Utica power system requires some storage to operate it at full capacity on a reasonable load factor. Engineers representing the company have stated that 60 second-feet are required to



operate the present installation in the Murphy power plant and that 80 second-feet at the intake of the conduit, which is 22.6 miles long, will furnish this amount at the power house. An estimate was made

of the storage required in addition to present storage of 9,000 acre-feet, to maintain a flow of 80 second-feet on a 75 per cent load factor. It is shown in Table No. 4 to be approximately 9,000 acre-feet, which is the amount the Utica Mining Co. requests permission to develop in the Spicers Meadows Reservoir as its first step.

38. The capacity of the Murphy project for 90 per cent of the time, with a total of 18,000 acre-feet of storage, as described in the foregoing paragraph has been estimated to be 2,500 horsepower.[1]

39. A reasonable method of providing for the increase in load on the Utica system or for the increase in sales by the system to other power companies would seem to be—

First. The construction of a dam at Spicers Meadows to a capacity of 9,000 acre-feet.

Second. The increase in capacity of Spicers Meadows to 62,000 acre-feet, the construction of the Utica conduit on a new grade and to a capacity of 410 second-feet, and the construction of the Collierville power house, which would then have an average power output during the period 1917–1921 of 39,000 horsepower, and an output about 13 per cent greater over long periods.

Third. The construction of either the North Fork Stanislaus River project No. 1, with estimated average output (1917–1921) of 16,000 horsepower, or the construction of North Fork Stanislaus River project No. 2, including Ramsey Meadows, with storage of 16,600 acre-feet with estimated average output of 20,500 horsepower.

40. The application referred to in the commission's instructions was made by Emma Rose, Anna G. Lane, and Hobart Estate Co., the owners of the Utica Mining Co. It requests the right to develop Spicer Reservoir to an initial storage of 9,000 acre-feet and an ultimate storage of 62,000 acre-feet.

41. The application is in general line with the logical development of power on the North Fork, provided that the enlarged storage right be conditioned on the utilization of maximum feasible head obtainable by the construction of the Collierville power plant and a limitation of the use through the Murphy power plant of the water required for domestic, mining, and irrigation purposes.

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[1] Actual records are available of flow of North Fork Stanislaus River at intake of Utica conduit from July, 1914, to September, 1920—approximately six years.

Table No. 3 shows that the year 1919–20 was the worst of this period, but Table No. 1 shows that the low flow extended over 8 months of this year, which can be neglected since the period of record is about 75 months.

The year with next lowest index in this period is 1917–18. Table No. 4 shows that it would have required in addition to present 9,000 acre-feet storage 9,660 acre-feet storage in Spicers Meadows to have maintained a flow of 60 second-feet at intake of Utica conduit. As this is but slightly in excess of the initial 9,000 acre-feet proposed, the flow available 90 per cent of the time is estimated as 60 second-feet

Head at power house, fore bay to tailrace, 527 feet.

Power capacity $60 \times 527 \times 0.08 = 2{,}500$ horsepower.

No deduction is made for loss of water in conduit.

4. CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

As a result of its investigations the board has come to the following general conclusions in regard to the uses of the Stanislaus River:

a. Power on the forks of the Stanislaus River can best be developed by high head projects supplied by long conduits.

b. Development of power on the North Fork can best be completed by the development of the fall between the present constructed reservoirs of the Utica Mining Co. and the backwater from the proposed Robinson's Ferry project, approximate elevation 1,050 feet, by the construction of long conduits. The lowest power house (Collierville power house) should be located on the Stanislaus River near the Stanislaus plant of the Sierra & San Francisco Power Co. and release its water above approximate elevation 1,050 feet.

c. There will be some increase in irrigation and domestic use in the area supplied by the system of the Utica Mining Co. in the foothills of the Stanislaus and Calaveras drainage basins. This use is worthy and it is for the best interests of the State that it be allowed to increase. However, the conservation of the natural power resources of the Stanislaus River requires that all water not needed for irrigation, mining, and domestic uses in this area be ultimately dropped through the proposed Collierville plant of the Utica Mining Co.

d. Power development on the Middle Fork can best be completed by the construction of projects developing the fall of the stream above the diversion of the Stanislaus project of the Sierra & San Francisco Power Co. by means of long conduits. Further developments for storage may take place on this fork by the construction of the Donnells Flat, Beardsley Flat and other reservoirs as economic conditions increase the value of storage on this fork.

e. The development of power on the South Fork can be continued by the construction of at least one plant above the Spring Gap diversion and one plant between this Spring Gap diversion and the Phoenix diversion. Further storage developed for supplying irrigation needs in the foothills of the Stanislaus and Tuolumne drainage basins may justify an increase in the installation of the Phoenix plant of the Sierra & San Francisco Power Co.

f. Power on the Stanislaus River proper below the forks and below approximate elevation 1,050 feet, which is the elevation of the stream bed opposite the Stanislaus plant of the Sierra & San Francisco Power Co., can best be developed by comparatively high dams impounding large storage primarily valuable for irrigation.

g. Storage sites on the North and Middle Forks of the Stanislaus River are chiefly valuable for power on account of their small capacity as compared with storage sites on the main stream and of the small amount of irrigable land in the mountains and foothills.

h. Additional storage on the South Fork may be needed for increase in irrigation and domestic use in the foothill areas in the Tuolumne and Stanislaus watersheds now supplied by the Phoenix system of the Sierra & San Francisco power system.

i. Storage sites on the main stream can be developed to a capacity, should foundations prove suitable as is indicated by surface conditions, sufficient to more than supply the Oakdale and South San Joaquin irrigation districts with all water needed adequately to irrigate the cultivable lands of these districts. Stored water on the Stanislaus will then be available for diversion to portions of the Sacramento-San Joaquin Basin not within the Stanislaus drainage area. (The Oakdale, South San Joaquin, and Modesto irrigation districts occupy all the valley area of the Stanislaus drainage. Modesto irrigation district receives its water supply from the Tuolumne River).

RECOMMENDATIONS

On the basis of the foregoing conclusions it is recommended—

a. That the development of power drop by conduits on the North and Middle Forks be permitted above approximate elevation 1,050 feet provided that these developments do not by-pass the Ramsey Meadows, Donnells Flat, or Beardsley Flat reservoir sites, unless these sites are proven by careful investigations to be infeasible for the development of economic storage, or other feasible storage sites are discovered and proposed as alternates to those above mentioned.

b. That applications for license to develop storage sites on the main Stanislaus River below elevation 1,050 feet to a maximum economical extent and with power use secondary to irrigation use be allowed.

c. That the development of further storage on the South Fork for domestic and irrigation use in the foothills of the Stanislaus and Tuolumne drainage basins through the Phoenix system of the Sierra & San Francisco Power Co. is for the best interests of the State and should be allowed when the demand increases beyond the present supply of the system.

d. That the application of the Utica Mining Co. for license for the development of Spicers Meadows Reservoir be allowed to a capacity sufficient to run the present installation in the plants of the company continuously throughout the year on reasonable load factor, but that the two following stipulations be included in the license: First, that the capacity of penstock and installation of the Murphy power plant be not increased unless such increase is necessary to utilize water required to supply an increase in the demand for domestic and irrigation purposes in the area under the Utica system; second, that should the Utica Mining Co. fail to apply for the right to develop additional storage and submit plans for its economical use when the public interest demands such storage, a license therefor may be granted to other interests.

TABLES

TABLE No. 1.—*Mean monthly flow of North Fork Stanislaus River at intake of Utica conduit. (Values in second-feet)*

Month	1914	1914–15	1915–16	1916–17	1917–18	1918–19	1919–20
October		54.9	40.6	74.9	44.1	45.9	31.4
November		46.0	42.0	75.0	48.7	54.5	22.7
December		55.2	67.9	152	51.8	86.0	45.0
January		64.5	321	101	37.9	57.9	53.4
February		165	573	229	77.8	128	66.3
March		462	1,190	359	302	234	269
April		1,280	1,990	1,250	1,150	907	718
May		2,000	2,290	1,430	1,180	1,580	1,570
June		1,450	1,170	1,700	593	262	584
July	118	229	240	229	163	70.9	91.0
August	57.0	62.6	74.8	71.7	59.1	48.0	53.0
September	58.1	59.4	72.4	70.3	50.5	33.3	46.7
Mean		495	660	477	313	294	297

TABLE No. 2.—*Stanislaus River seasonal run-off data*[1]

Season (begins Oct. 1)	Index of seasonal wetness, Division K	Depth of run-off in inches	Run-off index	Estimated seasonal run-off in acre-feet. (Above main agricultural area)	Distribution of seasonal run-off by months as shown by U.S.G.S. records
					Per cent
1871–72	122	35.4	135	1,860,000	January 7.1
1872–73	86	18.3	70	959,000	February 7.9
1873–74	87	18.5	70	970,000	March 16.6
1874–75	61	9.2	35	482,000	April 17.4
1875–76	154	55.8	213	2,930,000	May 22.7
1876–77	34	7.8	30	408,900	June 17.7
1877–78	112	30.0	114	1,570,000	July 5.6
1878–79	78	15.7	60	823,000	August 1.2
1879–80	105	26.5	101	1,390,000	September ... 0.5
1880–81	87	18.5	70	970,000	October 0.6
1881–82	85	18.0	69	944,000	November ... 0.9
1882–83	88	19.5	74	1,020,000	December ... 1.8
1883–84	135	43.0	164	2,260,000	
1884–85	67	11.1	42	582,000	
1885–86	129	39.5	150	2,070,000	
1886–87	68	11.8	45	619,000	
1887–88	64	10.3	39	540,000	
1888–89	74	13.7	52	718,000	
1889–90	174	68.2	260	3,580,000	
1890–91	86	18.3	70	959,000	
1891–92	90	20.0	76	1,050,000	
1892–93	132	41.0	156	2,150,000	
1893–94	122	35.5	135	1,860,000	
1894–95	148	51.5	196	2,700,000	
1895–96	104	26.4	101	1,380,000	
1896–97	124	36.7	140	1,920,000	
1897–98	62	9.5	36	498,000	
1898–99	89	19.6	75	1,030,000	
1899–1900	103	25.8	98	1,350,000	
1900–1901	129	39.5	150	2,070,000	
1901–1902	97	23.0	88	1,210,000	
1902–1903	108	23.9	91	1,254,800	
1903–1904	108	38.5	147	2,019,900	
1904–1905	108	16.3	62	848,400	

Measured seasonal discharge in acre-feet at U.S.G.S. gaging station.
[2] 479,200
2,014,800
844,000

[1] Taken from Bulletin No. 5, State of California, Department of Public Works, Division of Engineering and Irrigation.

[2] Partial record, May to September, inclusive.

TABLE No. 2.—*Stanislaus River seasonal run-off data*—Continued

Season (begins Oct. 1)	Index of seasonal wetness, Division K	Depth of run-off in inches	Run-off index	Estimated seasonal run-off in acre-feet. (Above main agricultural area)	Distribution of seasonal run-off by months as shown by U.S.G.S. records
1905–1906	139	45.4	173	2,383,200	2,378,800
1906–1907	148	53.3	203	2,803,500	2,799,100
1907–1908	64	11.4	43	597,800	593,500
1908–1909	119	36.1	138	1,897,100	1,892,700
1909–10	98	26.0	99	1,364,800	1,360,400
1910–11	133	44.2	168	2,322,900	2,318,900
1911–12	62	11.3	43	590,700	587,000
1912–13	58	9.6	37	506,700	494,000
1913–14	117	30.4	116	1,601,900	1,584,400
1914–15	114	24.3	93	1,277,500	1,274,900
1915–16	94	30.6	117	1,611,500	1,609,200
1916–17	82	26.2	100	1,362,800	1,360,900
1917–18	77	15.5	59	805,700	804,100
1918–19	99	14.4	55	749,800	748,600
1919–20	76	13.8	53	718,000	712,700
1920–21	110	23.4	89	1,219,500	1,218,600

SUMMARY OF ESTIMATED RUN-OFF

	Acre-feet	Depth in inches	Acre-feet per square mile	Season
Mean seasonal	1,376,000	26.24	1,400.0	
Maximum seasonal	3,580,000	68.20	3,642.0	1889–90
Minimum seasonal	408,900	1.20	64.0	1876–77
Mean during July	76,700	1.46	78.0	
Maximum during July	318,200	6.10	324.0	1905–1906
Minimum during July	3,520	0.07	3.6	1876–77
Mean during August	16,400	0.30	17.0	
Maximum during August	64,000	1.20	65.0	1906–1907
Minimum during August	0	0.00	0	1913–14

TABLE NO. 3.—*Estimate of ultimate power that can be economically developed on North Fork Stanislaus River*

[Prepared by Walter M. Coffey, junior engineer, United States Engineer Office]

NOTE: All tabular values are in second-foot months except in columns 9, 16, 22, and 23

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17		18	19	19a	20	21	22	23
																Flow from 48.4 square miles below No. 2 and above Utica intake								
Year and month	Natural run-off at all upper reservoirs	Stored or released	Storage in all upper reservoirs (capacity, 73,440 acre-feet or 1,224 second-foot months)	Flow from 31 square miles below upper reservoirs and above No. 1 intake	Controlled flow to No. 1 project	Utilized, No. 1 project (conduit capacity, 250 second-feet)	Wasted	Horsepower developed, No. 1 project (head, 1,130 feet)	Flow from 45.7 square miles below No. 1 intake above No. 2 intake	Stored or released, Ramsey Reservoir	Storage in Ramsey Reservoir (capacity, 16,800 acre-feet or 277 second-foot months)	Controlled flow to No. 2 project	Utilized, No. 2 project (conduit capacity, 350 second-feet)	Wasted	Horsepower developed, No. 2 project (head, 1,060 feet)	North Fork, 18.2 square miles	Beaver Creek, 30.2 square miles (tunnel capacity, 50 second-feet)	Controlled flow to Utica intake	Utilized by Murphy project (50 second-feet) [1]	Controlled flow to No. 3 project	Utilized, No. 3 project (conduit capacity, 360 second-feet)[1]	Wasted	Horsepower developed No. 3 project (head, 2,100 feet)	Total horsepower developed
1917—July	88.1	−53.1	1,170.9	26.8	168	168	0	15,180	64.0	0	277	232	232	0	19,660	25.5	42.4	299.9	50	249.9	249.9	0	41,980	76,820
August	18.1	−140.6	1,030.3	9.3	168	168	0	15,180	20.0	−38	239	226	226	0	19,160	5.5	9.2	240.7	50	190.7	190.7	0	32,040	66,380
September	8.9	−153.9	876.4	5.2	168	168	0	15,180	19.0	−39	200	226	226	0	19,160	3.0	5.0	234.0	50	184.0	184.0	0	30,910	65,250
October	6.3	−205.4	[2]671.0	3.7	168	168	0	15,180	12.3	−48.7	[2]151.3	226	226	0	19,160	2.2	3.6	231.8	50	181.8	181.8	0	30,540	64,880
November	14.7	−146.1	524.9	7.2	168	168	0	15,180	13.2	−44.8	106.5	226	226	0	19,160	4.2	7.0	237.2	50	187.2	187.2	0	31,450	65,790
December	16.5	−143.2	381.7	8.3	168	168	0	15,180	14.5	−43.5	63.0	226	226	0	19,160	4.9	8.1	239.0	50	189.0	189.0	0	31,750	66,090
1918—January	14.7	−146.1	235.6	7.2	168	168	0	15,180	10.6	−47.4	15.6	226	226	0	19,160	4.2	7.0	237.2	50	187.2	187.2	0	31,450	65,790
February	30.0	−124.7	110.9	13.3	168	168	0	15,180	19.6	−15.6	0	203.2	203.2	0	17,220	7.8	13.0	224.0	50	174.0	174.0	0	29,230	61,630
March	116.2	+5.5	116.4	57.3	168	168	0	15,180	84.5	+26.6	26.5	226	226	0	19,160	33.7	50.0	309.7	50	259.7	259.7	0	43,630	77,970
April	476	+476	592.4	227	227	200	27	18,080	311	+250.5	277.0	287	280	7.5	23,730	133.3	50	470.8	50	420.8	290.0	130.8	48,700	90,510
May	463	+463	1,055.4	228	228	200	28	18,080	330	0	277.0	558	280	278	23,730	134.2	50	742.2	50	692.2	290.0	402.2	48,700	90,510
June	235	+168.6	1,224	109.5	175.9	175.9	0	15,900	160.5	0	277.0	336.4	280	56.4	23,730	65.7	50	452.1	50	402.1	290.0	112.1	48,700	88,330
July	59.9	−73.6	1,150.4	29.5	163	163	0	14,730	45.5	−12.5	264.5	221	221	0	18,750	17.4	28.9	267.3	50	217.3	217.3	0	36,510	69,990
August	15.8	−139.5	1,010.9	7.7	163	163	0	14,730	16.5	−41.5	223.0	221	221	0	18,750	4.5	7.6	233.1	50	183.1	183.1	0	30,760	64,240
September	31.1	−116.9	894.0	15.0	163	163	0	14,730	27.9	−30.1	192.9	221	221	0	18,750	8.8	14.5	244.3	50	194.3	194.3	0	32,640	66,120
October	19.2	−181.7	[2]712.3	9.5	163	163	0	14,730	14.0	−47.0	[2]145.9	221	221	0	18,750	5.6	9.3	235.9	50	185.9	185.9	0	31,230	64,710
November	19.4	−134.1	578.2	9.5	163	163	0	14,730	15.5	−42.5	103.4	221	221	0	18,750	5.6	9.3	235.9	50	185.9	185.9	0	31,230	64,710
December	32.4	−114.6	463.6	16.0	163	163	0	14,730	24.0	−34	69.4	221	221	0	18,750	9.4	15.9	246.3	50	196.3	196.3	0	32,980	66,460
1919—January	22.0	−130.2	333.4	10.8	163	163	0	14,730	16.2	−41.8	27.6	221	221	0	18,750	6.4	10.6	238	50	188.0	188.0	0	31,580	65,060
February	50.0	−90.5	242.9	22.5	163	163	0	14,730	32.4	−25.6	2.0	221	221	0	18,750	13.1	21.7	255.8	50	205.8	205.8	0	34,570	68,050
March	96.4	−18.9	224.0	47.7	163	163	0	14,730	65.5	+7.5	9.5	221	221	0	18,750	28.0	46.5	295.5	50	245.5	245.5	0	41,240	74,720
April	378	+378	602.0	180	180	180	0	16,270	246	+188.0	197.5	238	238	0	20,180	105.8	50	393.8	50	343.8	290.0	53.8	48,700	85,150
May	624	+622	1,224	307	309	200	109	18,080	442	+79.5	277.0	671.5	280	391.5	23,730	181	50	902.5	50	852.5	290.0	562.5	48,700	90,510
June	100.8	−14.0	1,210.0	48.2	163	163	0	14,730	71.0	0	277	234	234	0	19,840	28.3	47.0	309.3	50	259.3	259.3	0	43,560	78,130
July	27.2	−125.8	1,084.0	10.2	163	163	0	14,730	19.8	−27.2	249.8	210	210	0	17,800	7.9	13.1	231.0	50	181.0	181.0	0	30,800	63,330
August	8.5	−150.3	934.1	4.2	163	163	0	14,730	13.4	−33.6	216.2	210	210	0	17,800	2.5	4.1	216.6	50	166.6	166.6	0	28,000	60,530
September	0	−163.0	771.1	0	163	163	0	14,730	9.0	−38.0	178.2	210	210	0	17,800	0	0	210.0	50	160.0	160.0	0	26,890	58,420
October	7.3	−199.6	[2]571.5	3.5	163	163	0	14,730	8.7	−41.3	[2]136.9	210	210	0	17,800	2.1	3.8	215.9	50	165.9	165.9	0	27,880	60,410
November	5.2	−155.3	416.2	2.5	163	163	0	14,730	6.2	−40.8	96.1	210	210	0	17,800	1.5	2.4	213.9	50	163.9	163.9	0	27,530	60,060
December	17.4	−137.1	279.1	8.5	163	163	0	14,730	12.6	−34.4	61.7	210	210	0	17,800	5.0	8.3	223.3	50	173.3	173.3	0	29,100	61,630
1920—January	20.7	−132.1	147.0	10.2	163	163	0	14,730	14.8	−32.2	29.5	210	210	0	17,800	5.9	9.9	225.8	50	175.8	175.8	0	29,540	62,070
February	25.4	−125.9	21.1	11.7	163	163	0	14,730	17.5	−29.5	0	210	210	0	17,800	6.9	11.5	228.4	50	178.4	178.4	0	29,960	62,490
March	100.0	−13.7	7.4	49.3	163	163	0	14,730	72.5	+25.5	25.5	210	210	0	17,800	29.0	48.2	287.2	50	237.2	237.2	0	39,850	72,380
April	311	+296.3	303.7	148.3	163	163	0	14,730	196.0	+149.0	174.5	210	210	0	17,800	87.1	50	347.1	50	297.1	290.0	7.1	48,700	81,220
May	621	+621.0	924.7	306.0	306	200	106	18,080	440.0	+102.5	277	643.5	280	363.5	23,730	180.0	50	873.5	50	823.5	290.0	533.5	48,700	90,510
June	228	+136.3	1,061.0	108.3	200	200	0	18,080	158.0	0	277	358	280	78.0	23,730	63.9	50	471.9	50	421.9	290.0	131.9	48,700	90,510
July	28.8	−167.3	904.0	14.2	200	200	0	18,080	25.4	−54.6	222.4	280	280	0	23,730	8.4	13.9	302.3	50	252.3	252.3	0	42,380	84,190
August	9.8	−185.4	718.6	4.8	200	200	0	18,080	13.6	−66.4	156.0	280	280	0	23,730	2.8	4.7	287.5	50	237.5	237.5	0	39,900	81,710
September	12.3	−181.9	536.7	5.8	200	200	0	18,080	12.4	−67.6	88.4	280	280	0	23,730	3.5	5.8	289.3	50	239.3	239.3	0	40,200	82,010
October	19.9	−217.7	[2]319.0	9.8	200	200	0	18,080	16.6	−66.4	[2]22.0	280	280	0	23,730	5.8	9.6	295.4	50	245.4	245.4	0	41,230	83,040
November	115.5	−29.0	290.0	55.5	200	200	0	18,080	82.2	+2.2	24.2	280	280	0	23,730	32.6	50	362.6	50	312.6	290.0	22.6	48,700	90,510
December	102.6	−46.7	243.3	50.7	200	200	0	18,080	75.2	−4.8	19.4	280	280	0	23,730	29.8	49.5	359.3	50	309.3	290.0	19.3	48,700	90,510
1921—January	83.2	−75.8	167.5	41.0	200	200	0	18,080	61.2	−18.8	0.6	280	280	0	23,730	24.1	40.1	344.2	50	294.2	290	4.2	48,700	90,510
February	122.0	−23.8	143.7	54.2	200	200	0	18,080	80.0	0	0.6	280	280	0	23,730	31.8	50	361.8	50	311.8	290	21.8	48,700	90,510
March	308	+256.0	399.7	148	200	200	0	18,080	213	+133.0	133.6	280	280	0	23,730	89.0	50	419.0	50	369.0	290	79.0	48,700	90,510
April	448	+448.0	847.7	213	213	200	13	18,080	300	+143.4	277	369.6	280	89.6	23,730	125.6	50	545.2	50	495.2	290	205.2	48,700	90,510
May	677	+376.3	1,224	333	333.7	200	133.7	18,080	481	0	277	1,114.7	280	834.7	23,730	196.0	50	1,310.7	50	1,260.7	290	1,020.7	48,700	90,510
June	509	0	1,224	243	752	200	552	18,080	362	0	277	1,114	280	834	23,730	142.6	50	1,306.6	50	1,256.6	290	966.6	48,700	90,510
Total	6,744.3	0		3,241.9	9,796.6	8,527.0	1,268.7	770,750	4,766.8	0		14,551.4	11,618.2	2,983.2	984,910	1,921.9	1,281.5	17,754.8	2,400	15,354.8	11,081.5	4,273.3	1,961,740	3,617,400
Mean					204	178		16,060				303	242		20,540			370	50	320	231		38,800	75,400

[1] Note capacity of conduit was taken as 410 second-feet—50 second-feet to Utica project and 360 to No. 3 power house.

[2] For purposes of evaporation, 47.4 second-foot months deducted—obtained as follows: Spicers, 900 acres + Utica-Union, 500 + silver, 180 = total, 1,580 acres $-\frac{0.6\times1,580\times3}{60}=47.4$ second-foot months.

[3] For purposes of evaporation, 3 second-foot months deducted—maximum area Ramsey Reservoir, 100 acres $\frac{0.6\times100\times3}{60}=3$ second-foot months.

TABLE No. 4.—*Estimate of storage required to operate system of Utica Mining Co. at present capacity on a reasonable load factor*

Present capacity of water wheels at Murphy's power plant	second-feet	60
Loss in 22 miles of conduit estimated by E. S. McCurdy	do	20
Required flow at intake of ditch	do	80
Average flow required on 75 per cent load factor	do	60
Present storage in all upper reservoirs	acre-feet	9,000

PERIOD AUGUST, 1917, TO FEBRUARY, 1918

Natural flow North Fork Stanislaus River at intake Utica conduit (estimated by deducting storage released from observed flow) August, 1917, to February, 1918	acre-feet	6,540
Present Utica storage	do	9,000
Total flow for 7 months of period	do	15,540
Average per month	do	2,220
Average per month (or)	second-feet	37
Additional storage required to maintain average flow of 60 second-feet for period (60–37) × 7 × 60	acre-feet	9,660

PERIOD AUGUST, 1918, TO JANUARY, 1919

Natural flow North Fork Stanislaus River at intake Utica conduit (estimated by deducting storage released from observed flow) August, 1918, to January, 1919	acre-feet	8,400
Present Utica storage	do	9,000
Total for 6 months' period	do	17,400
Average per month	do	2,900
Average per month (or)	second-feet	48
Additional storage required to maintain average flow of 60 second-feet for period (60–48) × 6 × 60	acre-feet	4,320

PERIOD JULY, 1919, TO FEBRUARY, 1920

Natural flow North Fork Stanislaus River at intake Utica conduit (estimated by deducting storage released from observed flow) July, 1919, to February, 1920	acre-feet	6,720
Present Utica storage	do	9,000
Total flow for 8 months	do	15,720
Average flow per month	do	1,965
Average flow per month (or)	second-feet	33
Additional storage required to maintain average flow of 60 second-feet for period (60–33) × 8 × 60	acre-feet	12,960

SUMMARY

Additional storage required to maintain average flow of 60 second-feet at intake of Utica conduit:

1917–18	acre-feet	9,660
1917–18	do	4,320
1918–19	do	12,960

No allowance is made for evaporation.

TABLE No. 5.—*Details of North Fork Stanislaus River projects*

No. 1 project:		
Elevation of diversion	feet	6,000
Length of conduit	miles	12
Capacity of conduit	second-feet	250
Loss of head in conduit	feet	120
Elevation of fore bay	do	5,880
Elevation of tailrace	do	4,750
Head	do	1,130
No. 2 project:		
Elevation of crest, Ramsey Meadows Dam	feet	4,735
Elevation of stream bed, Ramsey Meadows Dam	do	4,500
Capacity of reservoir	acre-feet	32,000
Capacity of reservoir for dam with crest elevation 4,685	do	16,600
Elevation of intake of conduit	feet	4,500
Length of conduit	miles	8
Capacity of conduit	second-feet	350
Loss of head in conduit	feet	80
Elevation of fore bay	do	4,420
Elevation of tailrace	do	3,360
Head	do	1,060
No. 3 project (Colliervile):		
Elevation of diversion	feet	3,347
Length of conduit (enlargement of present Murphy conduit)	miles	20
Capacity of conduit	second-feet[1]	410
Loss of head in conduit	feet	332
Elevation of fore bay	do	3,015
Elevation of tailrace	do	1,094
Head	do	1,921
Murphy project (constructed):		
Length of conduit	miles	22.6
Capacity of conduit	second-feet	88
Elevation of intake conduit	feet	3,347
Loss of head in conduit	do	406
Elevation of fore bay	do	2,941
Elevation of tailrace (on Angels Creek)	do	2,414
Head	do	527
Installation	kilowatts	1,500
Angels Camp project (constructed):		
Elevation of diversion on Angels Creek	feet	1,875
Length of conduit	miles	5.5
Capacity of Ross Reservoir	acre-feet	240
Elevation of fore bay	feet	1,842
Head	do	450
Installation	kilowatts	573

[1] The capacity proposed for the conduit of the No. 3 project is 410 second-feet, 50 second-feet of which is to supply the Murphy project.

TABLE No. 6.—*Details of Stanislaus River projects*

Robinson's Ferry:		
Location: About 2 miles above Melones, Calif.		
Approximate elevation of crest of dam	feet	1,050
Approximate elevation of stream bed	do	800
Approximate capacity of reservoir	acre-feet	90,000
Melones:		
Location: About one-fourth mile below mouth of Mormon Creek.		
Approximate elevation of crest of dam	feet	735
Approximate elevation of stream bed	do	540
Approximate capacity of reservoir	acre-feet	112,500
Black Creek:		
Location: Secs. 1 and 11, T. 1 S., R. 12 E., M. D. M.		
Approximate elevation of crest of dam	feet	540
Approximate elevation of stream bed	do	370
Approximate capacity of reservoir	acre-feet	96,000

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